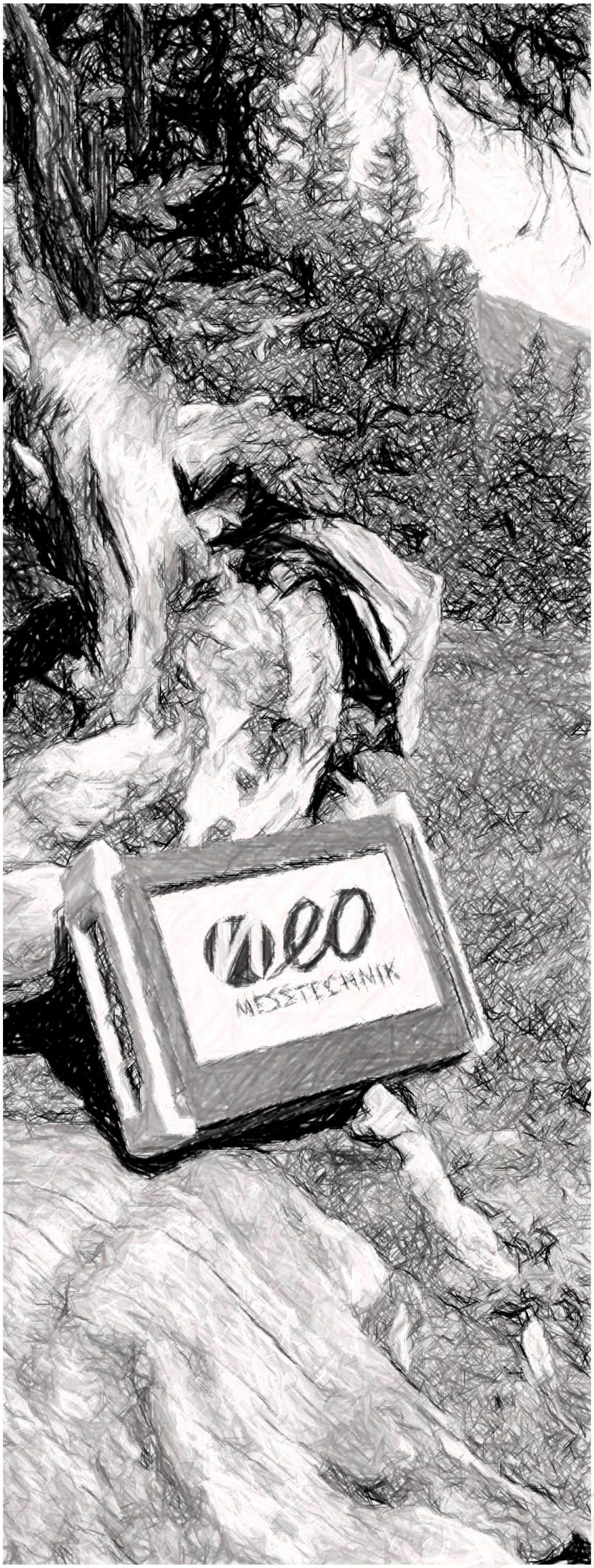


Application Note

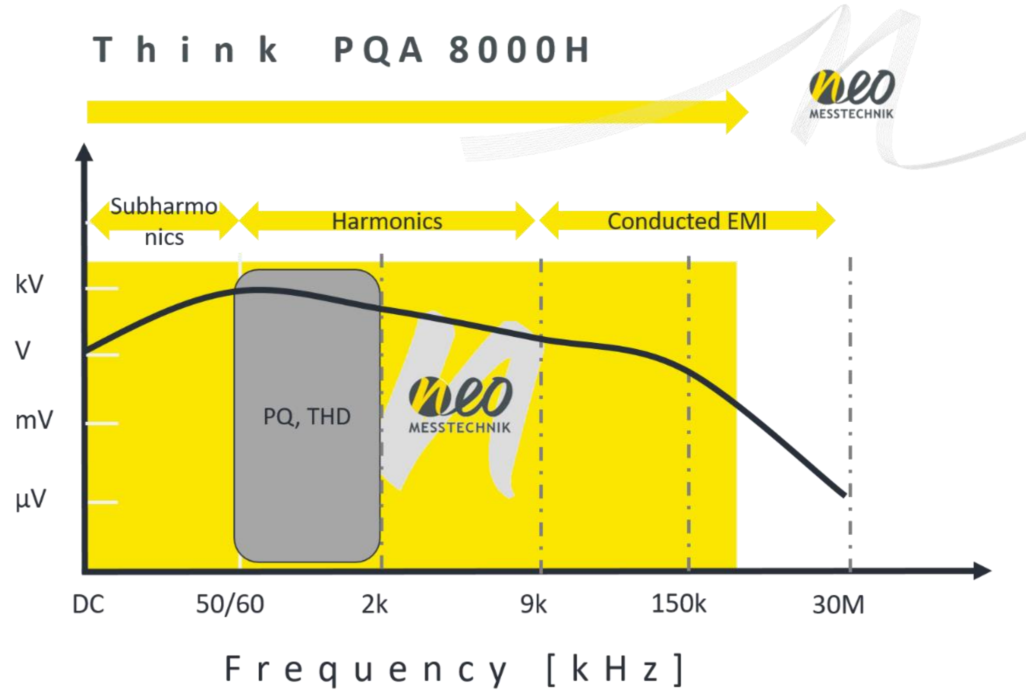
NEO PQ8000H – The Swiss Army Knife for Supraharmonics Analysis

Introduction

Power Quality Analysis does not stop at the 50th Harmonic order. Emissions in the frequency range from 9 kHz to 150 kHz are sources of electromagnetic interference to various electric equipment. Fortunately, all these problems do not concern engineers with the appropriate measurement equipment. Let's introduce the PQA8000H for troubleshooting Supraharmonic emissions - where its strengths really come into play ..

Keywords:
#PowerQuality #Supraharmonics #PQA8000H

Supraharmonics – At a Glance



Problem?

International and national standards often define emission limits up to 50th order Harmonics only. Although a majority of electric equipment will be compliant to these limits, the higher emissions starting from 2 kHz catch our attention. Modern electric equipment already operates with switching frequencies of up to 500 kHz.

The increase of power electronics and inverters will further drive the measurement demand of Higher Frequencies and Supraharmonics. Emissions in the frequency range from 9 kHz to 150 kHz are sources of electromagnetic interference to various electric equipment in the grid. Most of the PQ Analyzers are not able to catch up with this development.

Solution!

PQA 8000H. Easy answer. Simple measurement set-up. Intuitive Software. Powerful Measurement and Analysis. With the PQA 8000H troubleshooting Supraharmonic emissions simply can’t be made any easier.

Contact NEO Messtechnik

sales@neo-messtechnik.com +43 2642 20301

Supraharmonics

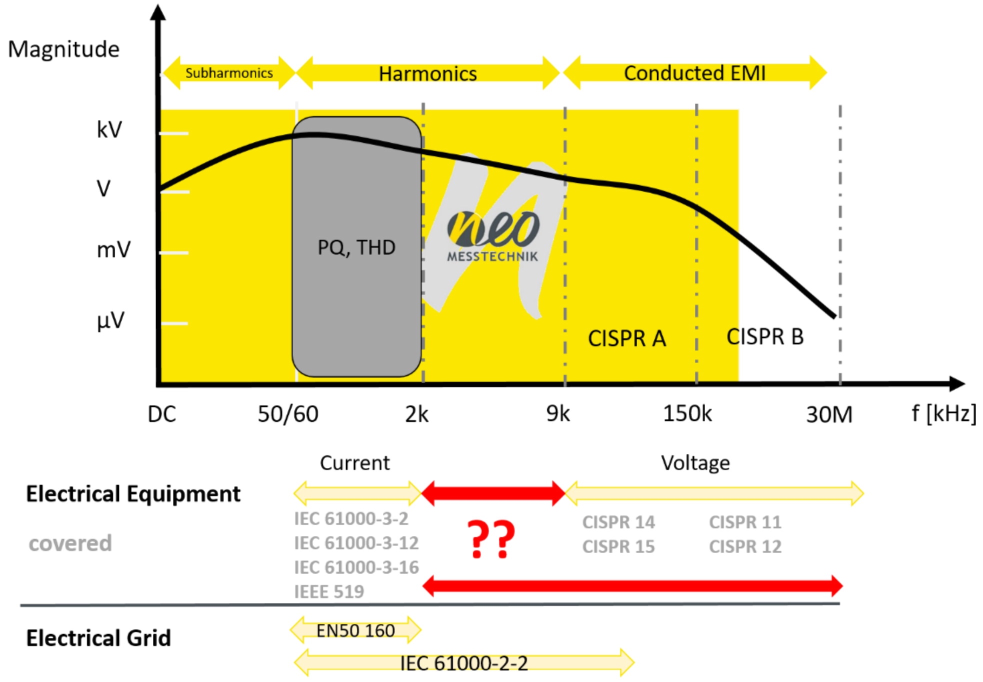
Analysis beyond the 50th harmonic

Although the specs of many PQ Analyzer and Monitoring solutions try to convince you otherwise – we can certainly assure you that Power Quality doesn't stop right at the 50th harmonic. Even more so, this is where the real challenges begins.

The sampling frequency should be, at least, twice the value of the expected measurement signal. By following the IEEE 519, analyzing up to the 50th has always been on the safe side. But if you limit yourself to this observation window, you miss the area beyond 2 kHz.

Definition

Supraharmonics are voltage and current emissions in the frequency range of above 2 kHz (up to 150 kHz or even 500 kHz). Until 2030 about 80% of all electric loads will connect to the grid via electronic interfaces. On one hand, this development promises a major increase in efficiency and better handling of electrical equipment. In exchange, the emission increase in the higher frequency range asks for more attention on our side.



As of right now, international and national standards often define emission limits up to 50th order Harmonics only. Although a majority of electric equipment will be compliant to these limits, the higher emissions starting from 2 kHz should catch our attention. Modern electric equipment already operates with switching frequencies up to 500 kHz.

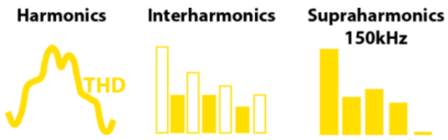
No standards. No problems?

The increase of power electronics and inverters will further increases the measurement demand of Higher Frequencies and Supraharmonics. Emissions in the frequency range from 9 kHz to 150 kHz are sources of electromagnetic interference to various electric equipment in the grid.

Implications on the grid

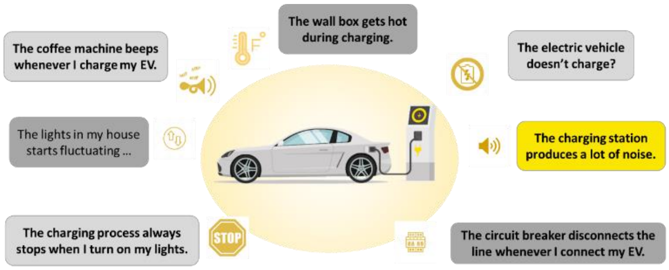
Supraharmonics cause problems and failures of electric equipment in various ways.

- Noise
- Thermal stress and ageing to electrical equipment
- Interferences of other electric equipment
- Damping/Deviations of the PLC signals



The closer the electric equipment is to the emission source, the higher are the implications. Electric Vehicle (EV) charging stations nowadays operate with switching frequencies at around 20-40 kHz, while inductive charging works in areas of 80-90 kHz.

These EV charging stations are popular examples where customers experience noise emissions, failures of other electrical equipment (coffee machines beep, hair dryers operate randomly) or thermal stress (heating).



In other words, it leads to poor Power Quality and distortion of PLC in Smart Meters. Already small disturbances in this frequency range can influence PLC signal transmission and therefore make it a substantial part of PQ investigations.

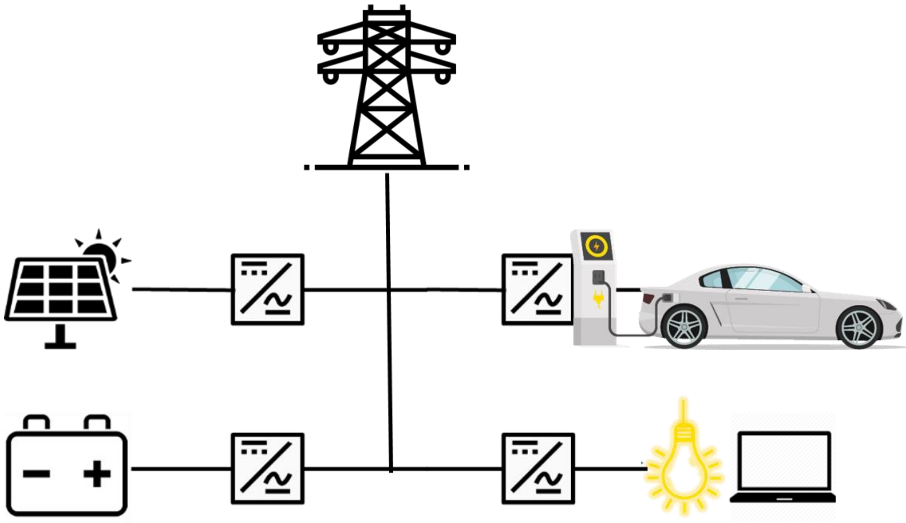
Furthermore

Higher frequencies propagate more at the outer skin of a conductor and lead to reduced effective usable cable section and thus a higher resistance.

List of Supraharmonic Effects

- Charging interruptions of EV's
- Malfunction of coffee machines
- Failures of smart meters (measurement error)
- Failure of smart meter communication (PLC)
- Whistling induction plates
- LED drivers disturbance, variation in light

Example: Sources of Supraharmonic Emissions



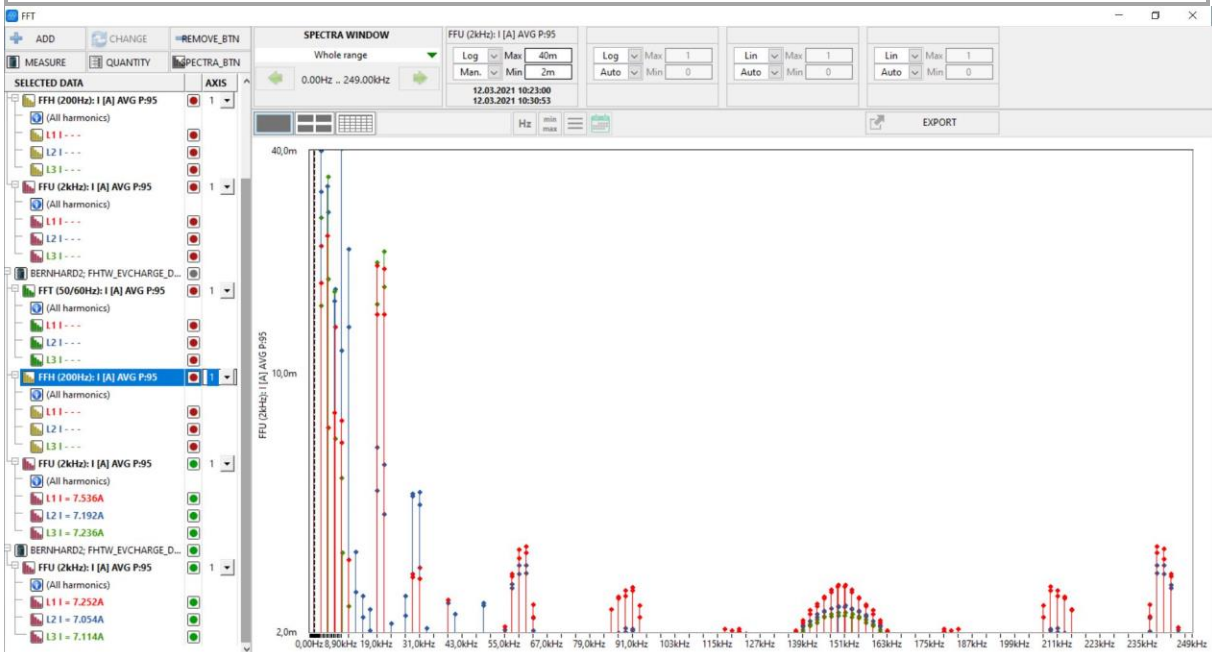
Importance of Measurement

Longtime measurements and Dynamic Analyses

Both 1min- and 10min average values are used to make statements about thermal stress and for normative evaluation within limit values.

The NEO advantage

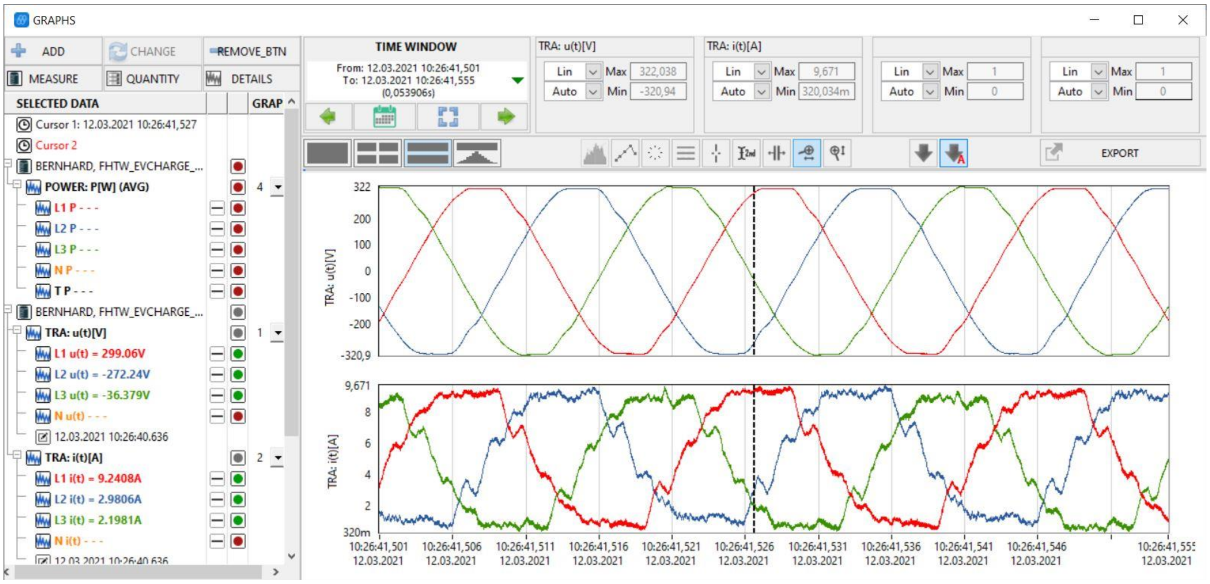
Using the PQA 8000H allows you to choose different average intervals, starting from 10 period values.



Short-time disturbances (so called Sub-Cycle phenomena) help to determine functional disorders and noise emissions, among others.

The NEO advantage

By means of envelope curve trigger the PQA8000H allows the detection of high-frequent short-time disturbances and analysis of sub-cycle behavior.



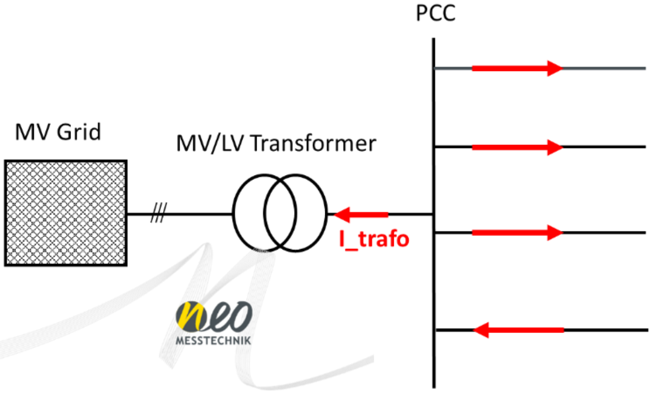
The importance of current measurement

Most measurement equipment only measures voltage and thereby **cannot** give any indications about the source or sink of Supraharmonics. The mere voltage measurement only partly helps for problem detection on the connection point and for normative assessments, e.g. according to IEC 61000-2-2.

The NEO advantage – Multi Channel Current Measurement

The PQA 8000H allows to measure up to 8 current channels to carry out in-depth Supraharmonic measurement and analyses.

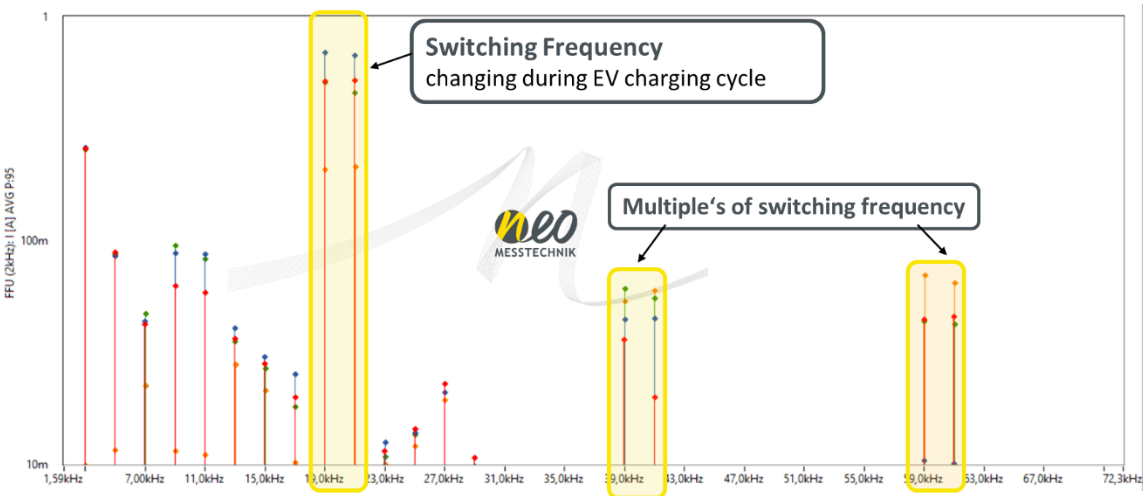
– Residential building with 20 flats and multi-channel measurements for rapid determination of the disturbing source and sink.



Further measurement effects

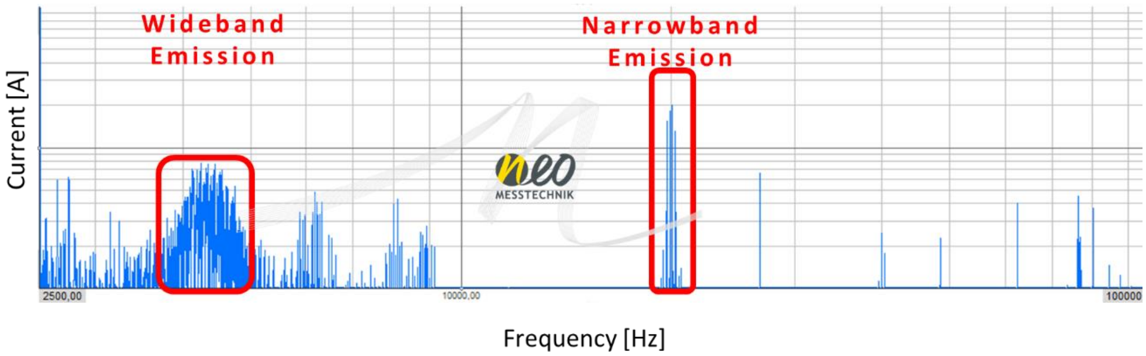
Changing Switching Frequency

We cannot regard switching frequencies to be constant – as example, we observed specific EV chargers that changed switching frequency throughout one charging operation from roughly 35 kHz to 38 kHz. These variations lead to changing grid impedance, filter properties and emissions that will result in other Supraharmonic bands, depicted in the following illustration (*ElmoNetQ 2020*).



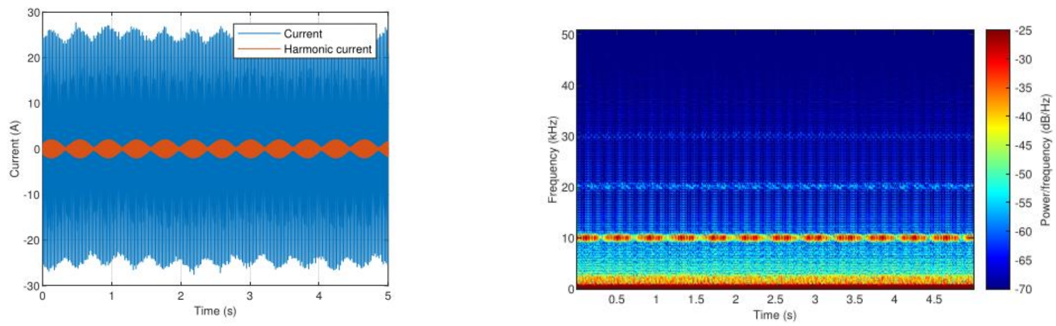
Wideband / Narrowband emissions

Depending on PE design, wideband or narrowband emission can occur. While narrowband emissions are centered on one frequency band, e.g. the switching frequency of 2 kHz, wideband emissions show up in multiple frequency bands.



Frequency Beating

When different devices of the same type (meaning the same converter) are connected close to each other, interactions can occur (multiple PV inverters, multiple EV charging stations). Supraharmonics can attenuate periodically (changing from +3A to -3A within milliseconds to seconds). This is because switching frequencies of multiple devices are never the same, even when they are from the same type (unavoidable differences due to manufacturing process … e.g. switching frequency of 16,001 kHz and 16,003 kHz). This can lead to RCD tripping, noise, etc.



Slangen, Wijk, Cuk, Cobben (2020) The Propagation and Interaction of Supraharmonics from Electric Vehicle Chargers in a Low-Voltage Grid

Frequency Intermodulation

Frequency Intermodulation is similar to the Frequency beating effect, but in this case the difference between switching frequencies is in the kHz range. This results in additional Supraharmonic components around switching frequencies and their multiples.

Challenges of simulations

In terms of simulations, engineers face a wide array of uncertain quantities in the higher-frequent area, from generation to consumption, which is subject of research and development:

- Unclear Damping behavior of HV/LV transformers
- LV-cables without shielding (determination of line-to-ground capacity almost impossible)
- Precise knowledge of power electronics on consumer/generation side necessary (switching frequencies, impedances)
- Various filter characteristics of power electronics
- Different switching frequencies of power inverter

Grid impedance

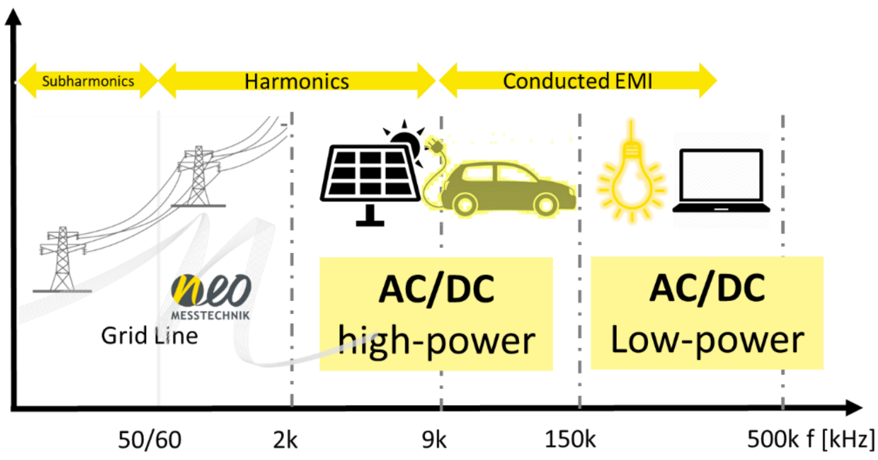
Measuring the frequency-dependent grid impedance allows drawing conclusions on the propagation and distribution of Supraharmonics (absolute value and angle) and determining how this impedance change is caused by the PE (consumer generator).

- Source-sink Model:
  - PE-device sink (TV) for a nearby sender of the interference (e.g. EV or PV)
- Importance of angle measurement
  - Real component negative –> resonance increase higher-frequencies (very rare)
  - Real component positive –> decrease of higher-frequencies

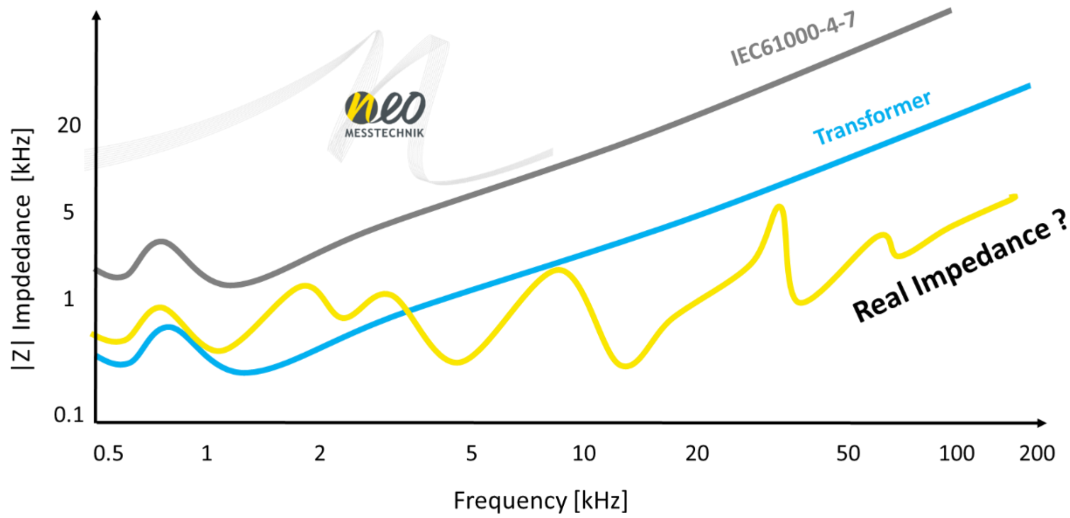
While low-frequency grid impedance is mainly influenced by the components of the grid (power lines, transformer), the high-frequency impedance depends mainly on the connected equipment.

Segmentation Grid impedance

- Up to 2 kHz:
  - Transformer / Distribution Line
- 2 kHz – 150 kHz:
  - AC/DC Conversion with EMV Filter with HIGH POWER (PV, ESS, EV)
- 150 kHz – 500 kHz:
  - AC/DC Conversion with EMV Filter with LOW POWER (LED, chargers)
  - Reason: higher resonance frequency of filters (to avoid RCD tripping)



Grid Impedance measurement

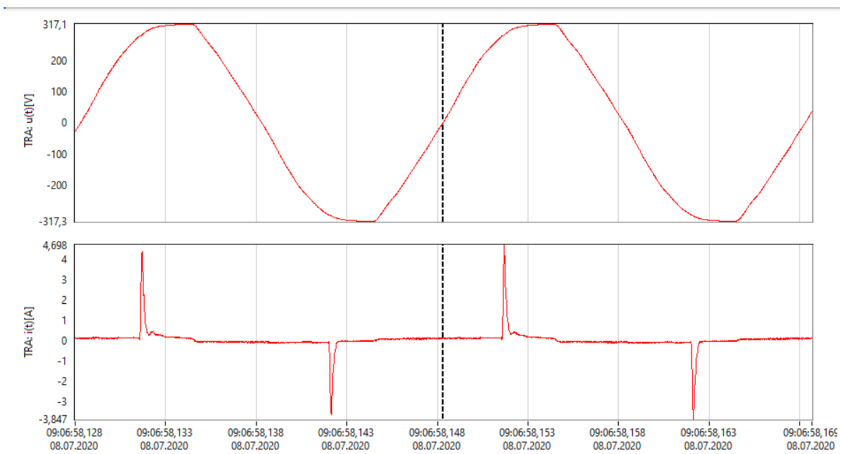


Influence Device impedance

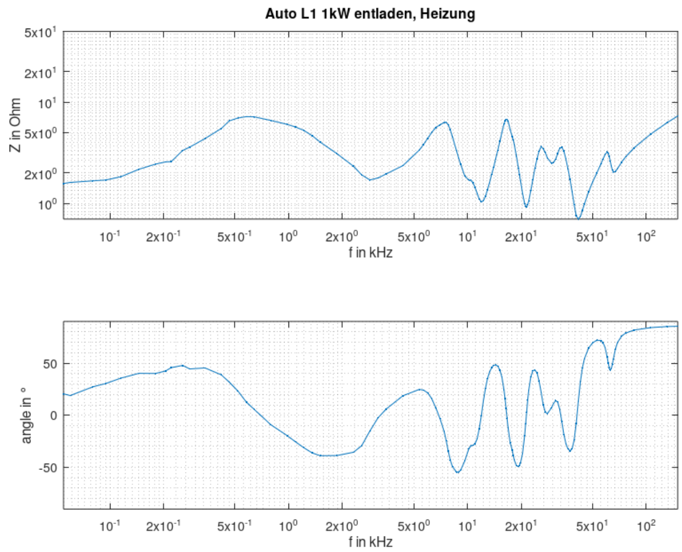
High-frequency grid impedance varies between 10 Ω and 200 Ω. Although device impedances should be as high as possible, low impedance values eventually take away PLC signals because of the higher transformer impedance.

Special measurement SUB-CYCLE impedance

This impedance is used to determine malfunctions changes during one net frequency cycle due to non-linear consumers, generators, peak current at around 90° angle.



Wideband Impedance Analysis up to 200kHz



Subcycle Impedance